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## (54) Locating method for mobile radio systems

(57) In order to locate the position of a mobile station (MS) of a mobile radio system, the distance (D1) of the mobile station from a base transceiver station (BTS1) is determined, or the distances (D1, D2, D3) of the mobile station from at least two base transceiver stations (BTS1, BTS2, BTS3) are determined and the position (40) is found by triangulation. In a GSM-type system, there is a predetermined known response delay between a particular signal received by the mobile station from the base transceiver station and a particular response transmitted from the mobile station to the base transceiver station; the distances (D1, D2, D3) can therefore be determined from the response delay and a measured period between transmission of the particular signal and reception of the particular response. In a GSM-type system, the mobile station transmits messages indicating the signal strengths of the base transceiver stations it is receiving, and on that basis the system allocates one of the base transceiver stations to the mobile station; in order to measure the distance between the mobile station and at least one other base transceiver station, the messages are modified in order to force a handover from one base transceiver station to another. In a CDMA-type system, the "soft hand-off" feature can be used to determine the distance to two or more BTSSs at the same time.

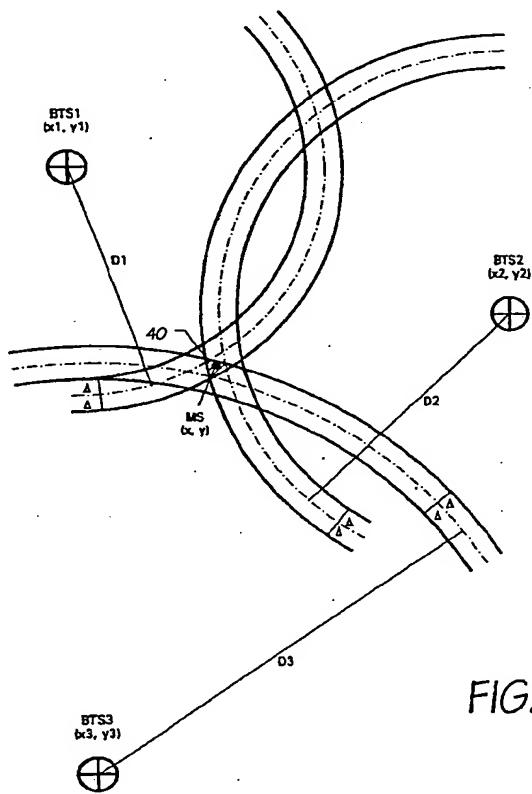


FIG. 5

## Description

This invention relates to mobile radio systems and to methods and apparatus to enable improvements to be made to such systems, or to enable added benefits to be obtained from, or new services to be provided by, such systems.

As is well known in the art, mobile radio systems, such as cellular telephone systems, employ a number of geographically spread base transceiver stations with which mobile stations, such as cellular telephones, can communicate by radio. Typically, while a mobile station is switched on, the system keeps track of the area in which the mobile station is situated, that is, that one of the base transceiver stations with which the mobile station is best able to communicate.

This invention was originally conceived to solve the problem of identifying geographical areas where communication between the fixed part of the system and mobile stations, or particular makes or models of mobile stations, is weak, for example where drop-out is a problem, so that the system may be modified, for example by the relocation or addition of base transceiver stations, so that the service provided by the system can be improved. However, it will be apparent from the following description that the invention has other uses.

In accordance with a first aspect of the present invention, there is provided a distance measuring method, comprising the steps of: measuring the temporal transmission delay of a radio signal between a base transceiver station of a mobile radio system and a mobile transceiver station of that system; and calculating the distance between the base station and the mobile station using the measured delay; wherein there is a predetermined known response delay between a particular signal received by the mobile station from the base transceiver station and a particular response transmitted from the mobile station to the base transceiver station, the transmission delay being determined from the response delay and a measured period between transmission of the particular signal and reception of the particular response. This aspect of the invention therefore takes advantage of the fact that, in a GSM-type system for example, there is a predetermined known response delay between a particular signal received by the mobile station from the base station and a particular response transmitted from the mobile station to the base station, and the transmission delay can be determined from that response delay and a measured period between transmission of the particular signal and reception of the particular response.

According to a second aspect of the invention, there is provided a position locating method, comprising the steps of: measuring the temporal transmission delay of a radio signal between a first base transceiver station of a mobile radio system and a mobile transceiver station of that system; and calculating the distance between the base station and the mobile station using the measured delay; wherein the base station is gener-

ally co-sited with another base station, the base stations performing sectored operation with overlap between the sectors and automatic handover between the base stations, and the distance measuring method being initiated when the mobile station is situated in the overlap of the sectors of the base stations; and the position of the mobile station is calculated using the calculated distance and a known sector of overlap of the base stations.

5 10 According to a third aspect of the invention, there is provided a position locating method, comprising the steps of: measuring the temporal transmission delay of a radio signal between a base transceiver station of a mobile radio system and a mobile transceiver station of that system; and calculating the distance between the base station and the mobile station using the measured delay; wherein at least part of the path of the radio signal is from the mobile station to the base station; the bearing of the mobile station from the base station is determined from the signal received by the base station; and the position of the mobile station is calculated using the calculated distance, the determined bearing and a known position of the base station. This aspect of the invention may make use of known so-called "smart antenna" technology.

15 20 25 It will be appreciated that the distance measuring method of the first aspect of the invention may be used in the position locating methods of the second and third aspects of the invention.

30 35 40 45 50 55 According to a fourth aspect of the invention, there is provided a position locating method comprising the steps of: performing any of the above methods in respect of a first such base station and the mobile station to calculate a first distance; performing any of the above methods in respect of a second such base station and the mobile station to calculate a second distance, the second base station being remote from the first base station; and calculating the position of the mobile station using the first and second calculated distances and known positions of the first and second base stations. In a system where a mobile station listens for call establishment messages from any number of base stations, the method can be performed by initiating calls sequentially from at least two base stations to the mobile station. On the other hand, in a system where there is automatic handover from one base station to another as a mobile station moves, the method can be performed at about the time of such a handover. If possible, this latter position locating method preferably further comprises the steps of: performing the method of any of the first three aspects of the invention in respect of at least one further such base station and the mobile station to calculate at least one further distance, the further base station(s) being remote from the first and second base stations; and using the or each further distance in the step of calculating the position of the mobile station. This therefore overcomes the ambiguity in triangulating an unknown position from the distances from only two known positions and also improves the

accuracy of the determined position. In the case where the system performs an automated handover process between the base stations in dependence upon circumstances unrelated to the position locating method, the delay measuring steps are preferably performed generally immediately before, at the time of, or immediately after such a handover. In the case of position location using three or more base stations, the two or more handovers between those base stations are preferably forced in a manner described below.

According to a fifth aspect of the invention, there is provided a position locating method, comprising the steps of: measuring a first property of a first communications link between a first base transceiver station of a mobile radio system and a mobile transceiver station of that system; calculating the distance between the first base station and the mobile station using the first measured property; measuring a second property of a second communications link between a second base transceiver station of the mobile radio system and the mobile transceiver station; calculating the distance between the second base station and the mobile station using the second measured property; and calculating the position of the mobile station using the first and second calculated distances and known positions of the first and second base stations; wherein the system performs an automated handover process between the base stations in dependence upon circumstances unrelated to the position locating method; and the property measuring steps are performed generally immediately before, at the time of, or immediately after such a handover.

The method may include the further steps of: measuring at least one further property of at least one further communications link between at least one further base transceiver station of the mobile radio system and the mobile station; calculating the distance between the or each further base station and the mobile station using the or each further measured property; and using the or each further distance in the position calculating step.

Preferably, each property which is measured is dependent on the temporal transmission delay of a radio signal between the mobile station and the respective base station. However, it may be possible that another property such as signal strength can be measured so as to enable the distance between the base station and mobile station to be calculated sufficiently accurately.

The method preferably further comprises the step of modifying the circumstances presented to the automated handover process so as to force such a handover to occur which would not occur without such modification. Thus, position location can be carried out at any desired time when the mobile station is within range of at least two base stations.

It will be appreciated that once the position of the mobile station has been determined, it may be plotted on a map. Furthermore, the position location method may be repeated so that the track (if any) of the mobile

station can be ascertained, and the track may be plotted on a or the map. Additionally the speed and/or direction of travel (if any) of the mobile station may then be determined.

As mentioned above, the invention was originally conceived for use in geographical surveying of the signal strength of the mobile radio system. However, the invention may have other uses, such as: locating the position of a caller who is making an emergency 999 call, for example as a result of a road accident when they are not sure of their exact position; tracking and locating stolen mobile telephones or stolen vehicles; vehicle fleet management; and generally as a service to tell users where they are.

In accordance with a sixth aspect of the present invention, there is provided a mobile radio system having means for performing the method of any of the first to fifth aspects of the invention.

In accordance with a seventh aspect of the present invention, there is provided a monitoring and message modification device for a mobile radio system, the device being operable to monitor messages regarding the strength or quality of signal between a mobile station and a base station of the system, and the device being selectively operable to modify such messages to indicate a better and/or worse strength or quality of the signal. In a GSM-type system, this device may be simply inserted in the Abis interface so as to enable the position location methods described above to be performed, without requiring any other modification to the GSM-type system. Reference in this connection is directed to European patent application 95300789.5

Specific embodiments of the present invention will now be described by way of non-limiting example with reference to the accompanying drawings in which:

- Figure 1 is a block diagram of the main components of a known GSM cellular mobile radio system;
- Figure 2 is a diagram showing how the position of a mobile station can be estimated from the signal delays between the mobile station and two base transceiver stations;
- Figure 3 is a timing diagram to illustrate how the signal delay can be determined;
- Figure 4 is a block diagram similar to Figure 1, but showing how the system is modified in accordance with an embodiment of the invention
- Figure 5 is a diagram showing how the position of a mobile station can be estimated from the signal delays between the mobile station and three base transceiver stations;
- Figure 6 is a diagram showing how the position of a mobile station can be estimated from the signal delay between the mobile station and a sectored base transceiver station; and
- Figure 7 is a diagram showing how the position of a

mobile station can be estimated from the signal delay between the mobile station and a base transceiver station having a "smart antenna" technology.

Referring to Figure 1, a GSM public land mobile network ("PLMN") 10 comprises a network and switching sub-system ("NSS") 12, which connects with a plurality of base station subsystems ("BSSs") 14. The BSSs 14 provide radio communication with mobile stations ("MSs") 16, only one of which is shown in Figure 1. The NSS 12 also communicates with the fixed public network 18, i.e. the public switched telephone network ("PSTN") and the integrated services digital network ("ISDN"). Therefore, calls can be wholly contained within the PLMN 10, or can be passed either way between the PLMN 10 and the PSTN/ISDN 18.

The NSS 12 includes mobile switching centres ("MSCs") 20 which are interconnected by dedicated connections or via the PLMN 10, and at least some of the MSCs 20 are gateway mobile switching centres ("GMSCs") 22, which handle calls directed to MSs 16 from outside of the PLMN 10, the GMSC 22 determining where the call should be routed to catch up with the required MS 16. Each MSC 20 may be connected to one or more of the BSSs 14, and the interface between a BSS 14 and its MSC 20 is standardised and referred to in GSM parlance as the "A" interface 23.

Each BSS 14 includes a base station controller ("BSC") 24 connected via the A interface 23 to the MSC 20 and controls a plurality of base transceiver stations ("BTSs") 26, the interface between the BSC 24 and its BTSs 26 being known in GSM parlance as the "Abis" interface 28. A plurality of BTSs 26 may be collocated at each site. Each BTS 26 has radio transmitters and receivers for providing radio coverage of a local area known as a "cell" so that communication can be established with MSs 16 across the radio interface 30.

In operation, each BTS 26 periodically transmits its identity. When an MS 16 is switched on, it listens to the identity or identities transmitted by the BTS or BTSs 26 of which it is within range and measures the received signal strength(s). When a connection is present between the MS 16 and a BTS 26, the MS 16 then periodically transmits messages indicating the received signal strength(s) of the BTS(s) 26. As a result, the PLMN 10 can choose which BTS 26 is best suited for communication with the MS 16. This information is kept up to date, and as the MS 16 moves the system can "handover" a MS 16 from one BTS 26 to another.

In accordance with an embodiment of the invention, in order to locate the position of a MS 16, the distance of the MS 16 from its BTS 26 is determined just before a handover, and just after a handover the distance of the MS 16 from its new BTS 26 is also measured. On the assumption that the distance moved by the MS 16 between the two distance measurements being taken is insignificant, the MS 16 can be determined by triangulation to be at one of two places, or in one of two areas

taking into account inaccuracies in the distance measurements. Referring to Figure 2, a mobile station MS is associated with a base transceiver station BTS1 located at a position  $(x_1, y_1)$ , and the measured distance from the MS to BTS1 is  $D_1 \pm \Delta$  immediately before a handover to a neighbouring base transceiver station BTS2 located at a position  $(x_2, y_2)$ . Immediately after the handover, the measured distance from MS to BTS2 is  $D_2 \pm \Delta$ . Given that the values  $x_1, y_1, x_2, y_2, D_1, D_2$  and  $\Delta$  are all known, it is determined from triangulation that the position  $(x, y)$  of the MS lies within one of the two hatched areas 32, 34.

In accordance with an embodiment of the invention, the distance between a BTS 26 and MS 16 is determined from signal delays as follows. In a GSM system, as well as other TDMA and CDMA systems, the transmission signals are separated into discrete bursts. Referring to Figure 3, each BTS 26 generates a broadcast channel "BCCH". The BTS 26 can register an absolute time reference  $t_0$  of the beginning of each burst which it transmits. The MS 16 receives the burst at a time  $t_1$ , which is delayed from time  $t_0$  by a period  $\tau_1$ . This burst is the last received burst prior to the MS 16 transmitting an access channel request on the RACH. The embodiment of the invention takes advantage of the fact that, in a GSM system, when the MS 16 first communicates to the BTS 26, it generates its access channel request on the RACH at a timing  $t_2$  of which is synchronised to the reception of the BCCH burst with a known fixed delay of period  $\sigma$ , which in a GSM system is three time slots, i.e.  $\sigma = 3 \times 576.92 \mu s = 1.73076 \text{ ms}$ . The access channel request on the RACH is received by the BTS 26 at time  $t_3$ , which is delayed from time  $t_2$  by a period  $\tau_2$ , and the BTS 26 registers the absolute time  $t_3$ . On the assumption that the distance which may be travelled by the MS 16 during the period  $\sigma$  is small, then the two delays  $\tau_1, \tau_2$  will be equal, and the BTS 26 can calculate the distance  $D$  to the MS 16 from the formula  $D = \frac{1}{2}c(t_3 - t_0 - \sigma)$ , where  $c$  is the speed of light.

In a GSM system, an alternative method of determining the distance of the MS 16 from the BTS 26 is to monitor the "timing advance" field in the "measurement result" message passed on the Abis interface 28. In a GSM system, the timing advance field can contain values from 0 to 63. The timing advance field is measured in terms of bit periods, with each bit period equating to  $3.692 \mu s$ . This results in timing advance bands equating to bands of  $\frac{1}{2}c \times 3.692 \mu s \approx 554 \text{ m}$  so that for a given timing advance value, the distance from the BTS is:

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<u>Timing Advance</u>	<u>Distance from BTS</u>
0	0 to 554 m
1	554 to 1108 m
2	1108 to 1662 m
:	:
63	34902 to 35456 m

The embodiment of the invention described above is operable to determine distances and locations at the time of a handover, and as described so far relies on handovers arising in the normal operation of the system. There now follows a description of a development whereby distances and locations can be determined on demand. Figure 4 of the drawings shows a modification of the system of Figure 1 in which a message monitoring and substitution unit ("MMSU") 36 is placed in the Abis interface 28 between each BTS 26 and its BSC 24, and the MMSUs 36 are controlled by a position location controller ("PLC") 38. The PLC 38 and MMSU 36 may be integrated with, or separate from, the BTS 26 and the BSC 24 components of the PLMN 10. The PLC 38 can control the MMSUs 36 so that they have no effect on the system, which therefore operates in the normal convention manner. However, the PLC 38 can also control the MMSUs 36 so that they monitor the signal strength messages passed by a particular MS 16, or a particular type of MS 16 (for example a particular make and model) or all MSs, via selected BTSs 26 to the system, and so that they can modify those messages so as to force a handover of the MS 16 from one BTS 26 to another on demand. The MMSUs 36 also collect the distance information from the BTSs 26 and supply it to the PLC 38 where it is processed in order to determine the location of each mobile station under analysis. Referring to Figure 5, suppose that the MS is transmitting messages that the signal strengths from BTS1, BTS2 and BTS3 are 10, 7 and 6, respectively, and that the MS is accordingly associated with BTS1. A distance measurement is carried out as described above with reference to Figure 3 to determine the distance D1 from the MS to BTS1. The MMSU for BTS1 then modifies the signal strength message from the MS, for example to specify that the signal strengths from BTS1, BTS2 and BTS3 are 0, 7 and 0, respectively, before the message is passed on to the BSC 24. As a result the system forces a handover from BTS1 to BTS2. A distance measurement is then carried out as described above with reference to Figure 3 to determine the distance D2 from the MS to BTS2. The MMSU for BTS2 then modifies the signal strength message from the MS, for example to specify that the signal strengths from BTS1, BTS2 and BTS3 are 0, 0 and 6, respectively, before the mes-

sage is passed on to the BSC 24. As a result the system forces a handover from BTS2 to BTS3. A distance measurement is then carried out as described above with reference to Figure 3 to determine the distance D3 from the MS to BTS3. The MMSU for BTS3 then ceases to modify the signal strength messages, as a result of which, and assuming the measured signal strengths have not changed, the system may perform a routine handover from BTS3 (signal strength 6) to BTS 1 (signal strength 10). As shown in Figure 5, having determined the distances D1 to D3 of the MS from BTS1 to BTS3, and knowing the locations of BTS1 to BTS3, the PLC 38 can then determine by triangulation the position of the MS as being within the hatched area 40. It will be appreciated that by using three or more BTSs, the ambiguity as to location area, as illustrated by the two hatched areas 32, 34 in Figure 2, is resolved, and also that the determined area is likely to be smaller.

It has been described above that the distances of the MS 16 from a plurality of BTSs 26 may be determined at the time of a routine handover arising as a result of the signal strengths received by the MS 16 from the BTSs 26, or at the time of a forced handover caused specifically for the purpose of calculating more than one distance. The distances may also be determined at times of other sorts of handover. For example, in GSM systems, it is known to have macro cells for which the BTSs 26 have a long range, for example due to the antennae being above roof level, and to have micro cells for which the BTSs 26 generally have a shorter range, for example due to the antennae being below roof level, and it is known to hand over a particular MS 16 from a micro cell to a macro cell covering the same area if that MS is adjudged to have a high speed of movement, so that subsequent handovers need not be so frequent, and conversely to hand over a particular MS 16 from the macro cell to a micro cell covering the same area if that MS is adjudged to have slowed down, so as to free up the capacity of the macro cell. The position of the MS 16 may therefore be calculated at the time of a handover from a macro cell to a micro cell, or vice versa. It is also possible that a handover could be forced between macro and micro cells for the purpose of position location, even though the speed of the MS 16 would not normally dictate such a handover. As another example, it is known to provide "graceful" shutdown of BTSs 26 when they are being taken out of action, by handing over the MSs 16 for which that BTS is responsible to one or more other BTSs. Position location of the MSs 16 may be performed at that time.

The methods used to perform the other types of handover can also be applied for the purpose of forcing handover to enable location to be determined.

An embodiment of the invention has been described above with reference to a GSM system, but it should be noted that the invention is also applicable to other type of cellular mobile radio system, including CDMA and TDMA.

In the arrangement described with reference to Fig-

ure 2, the location of the MS is determined at the time of a routine handover, and in Figure 5 at the time of a forced handover in the case of a GSM system. As an alternative, the CDMA system employs "soft hand-off", in which, when transferring from a first BTS to a second, a link is established between the MS and the second BTS (and possibly a third BTS) before the link with the first BTS is broken. Position location can therefore advantageously take place when the MS is in communication with two or more BTSs at the time of such a soft hand-off. As another alternative, in a system in which MSs monitor multiple BTSs listening for call establishment messages, the invention may be applied by causing a plurality of calls to be initiated from a plurality of BTSs to a particular MS. Each call would be established only long enough to determine the distance information, and then ended. More generally, the distance(s) of an MS 16 from any one or more BTSs 26 which can communicate with that MS 16 may be determined by establishing a link between the MS 16 and the or each BTS 26 solely for the purpose of determining the distance, and the link may be established at the request of the MS 16, the user of the MS 16, or the PLMN 10.

It will be appreciated that many other modifications and developments may be made to the invention. For example, Figure 6 illustrates how the present invention may be applied in the case of a BTS having three co-sited sectored transceivers with coverage areas 42, 44, 46 which overlap. With such a BTS, handovers can occur as a MS moves from one sector to the next through an area of overlap. By measuring the distance between the BTS and the MS in the manner described above with reference to Figure 3 immediately before and/or immediately after a handover, it will be appreciated that it is possible to determine an area 47 in which the MS is situated at that time from the measured distance and the particular area of overlap.

Figure 7 illustrates how the present invention may be applied in the case of a BTS which may employ "smart antenna" technology. With that technology, a BTS is able to determine, within limits, the bearing 50 of the MS with respect to the BTS. By also determining the distance 48 of the MS from the BTS in the manner described above with reference to Figure 3, it is possible to determine an area 52 in which the mobile station is situated.

In the detailed description set out above, handover is forced by modifying signal strength messages passed around the system. Alternatively, messages relating to other parameters such as signal quality may be modified in order to force a handover. Furthermore, in a system in which mobile stations can issue messages requesting handover, additional messages requesting handover may be generated, for example by units somewhat like the MMSUs 36 in Figure 4, in order to force a handover.

## Claims

### 1. A position locating method, comprising the steps of:

measuring a first property of a first communications link between a first base transceiver station of a mobile radio system and a mobile transceiver station of that system; calculating the distance between the first base station and the mobile station using the first measured property; measuring a second property of a second communications link between a second base transceiver station of the mobile radio system and the mobile transceiver station; calculating the distance between the second base station and the mobile station using the second measured property; and calculating the position of the mobile station using the first and second calculated distances and known positions of the first and second base stations; wherein the system performs an automated handover process between the base stations in dependence upon circumstances unrelated to the position locating method; and the property measuring steps are performed generally immediately before, at the time of, or immediately after such a handover.

### 2. A method as claimed in claim 1, including the further steps of:

measuring at least one further property of at least one further communications link between at least one further base transceiver station of the mobile radio system and the mobile station; calculating the distance between the or each further base station and the mobile station using the or each further measured property; and using the or each further distance in the position calculating step.

### 3. A method as claimed in claim 1 or 2, wherein each property which is measured is dependent on the temporal transmission delay of a radio signal between the mobile station and the respective base station.

### 4. A distance measuring method, comprising the steps of:

measuring the temporal transmission delay of a radio signal between a base transceiver station of a mobile radio system and a mobile transceiver station of that system; and calculating the distance between the base station and the mobile station using the measured

delay;

wherein there is a predetermined known response delay between a particular signal received by the mobile station from the base transceiver station and a particular response transmitted from the mobile station to the base transceiver station, the transmission delay being determined from the response delay and a measured period between transmission of the particular signal and reception of the particular response.

5. A position locating method, comprising the steps of:

measuring the temporal transmission delay of a radio signal between a first base transceiver station of a mobile radio system and a mobile transceiver station of that system; and calculating the distance between the base station and the mobile station using the measured delay;

wherein the base station is generally co-sited with another base station, the base stations performing sectored operation with overlap between the sectors and automatic handover between the base stations, and the distance measuring method being initiated when the mobile station is situated in the overlap of the sectors of the base stations; and

30 the position of the mobile station is calculated using the calculated distance and a known sector of overlap of the base stations.

6. A position locating method, comprising the steps of:

measuring the temporal transmission delay of a radio signal between a base transceiver station of a mobile radio system and a mobile transceiver station of that system; and

40 calculating the distance between the base station and the mobile station using the measured delay;

wherein at least part of the path of the radio signal is from the mobile station to the base station;

45 the bearing of the mobile station from the base station is determined from the signal received by the base station; and

the position of the mobile station is calculated using the calculated distance, the determined bearing and a known position of the base station.

7. A method as claimed in claim 5 or 6, wherein there is a predetermined known response delay between a particular signal received by the mobile station from the, or the first, base transceiver station and a particular response transmitted from the mobile station to that base transceiver station, the trans-

5 mission delay being determined from the response delay and a measured period between transmission of the particular signal and reception of the particular response.

8. A position locating method, comprising the steps of:

10 performing the method as claimed in any of claims 4 to 7 in respect of a first such base station and the mobile station to calculate a first distance;

15 performing the method as claimed in any of claims 4 to 7 in respect of a second such base station and the mobile station to calculate a second distance, the second base station being remote from the first base station; and calculating the position of the mobile station using the first and second calculated distances and known positions of the first and second base stations.

20 9. A method as claimed in claim 8, further comprising the steps of:

25 performing the method as claimed in any of claims 4 to 7 in respect of at least one further such base station and the mobile station to calculate at least one further distance, the further base station(s) being remote from the first and second base stations; and using the or each further distance in the step of calculating the position of the mobile station.

30 10. A method as claimed in claim 8 or 9, wherein:

35 the system performs an automated handover process between the base stations in dependence upon circumstances unrelated to the position locating method; and

40 the delay measuring steps are performed generally immediately before, at the time of, or immediately after such a handover.

45 11. A method as claimed in claim 1, 2, 3 or 10, further comprising the step of modifying the circumstances presented to the automated handover process so as to force such a handover to occur which would not occur without such modification.

50 12. A method as claimed in any one of claims 1 to 3 and 8 to 11, wherein the distance of the mobile station from each base station is calculated as a result of calls made to the mobile station from the base stations sequentially on demand.

55 13. A method as claimed in any one of claims 1 to 3 and 5 to 12, further comprising the step of plotting the determined position on a map.

14. A method as claimed in any one of claims 1 to 3 and 5 to 13, which is repeated so that the track (if any) of the mobile station can be ascertained.

15. A method as claimed in claim 14, further comprising the step of plotting the track on a, or the, map. 5

16. A method as claimed in claim 14 or 15, further comprising the step of determining the speed and/or direction of travel (if any) of the mobile station. 10

17. The use of a method as claimed in any preceding claim in a geographical survey of the signal strength of the mobile radio system. 15

18. A mobile radio system having means for performing the method of any of claims 1 to 16.

19. A monitoring and message modification device for a mobile radio system, the device being operable to monitor messages regarding the strength or quality of signal between a mobile station and a base station of the system, and the device being selectively operable to modify such messages to indicate a better and/or worse strength or quality of the signal. 20 25

20. A position locating method, a distance measuring method, the use of such a method in a geographical survey, a mobile radio system, or a monitoring and message modification device substantially as described with reference to the drawings. 30

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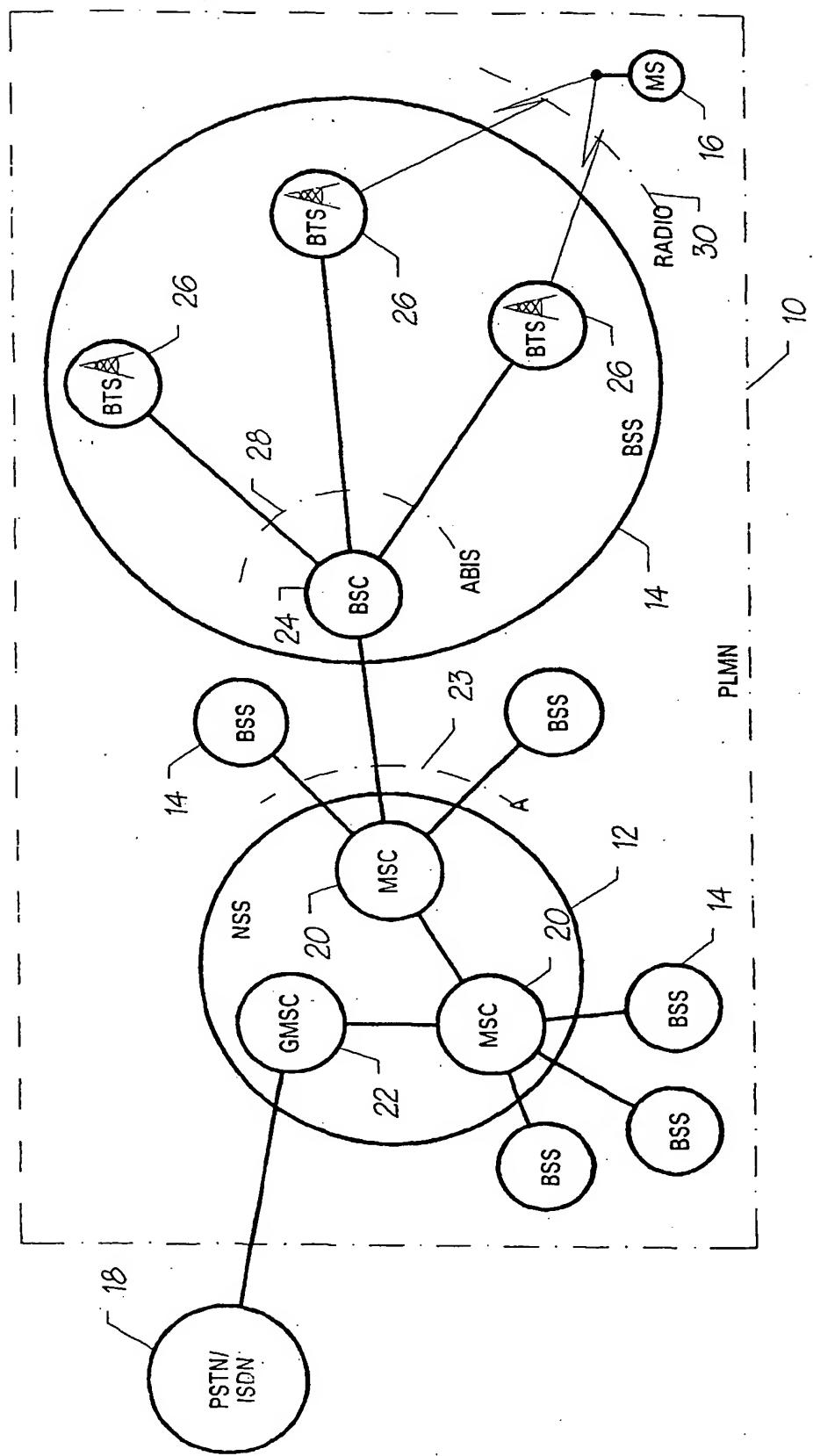


FIG. 1

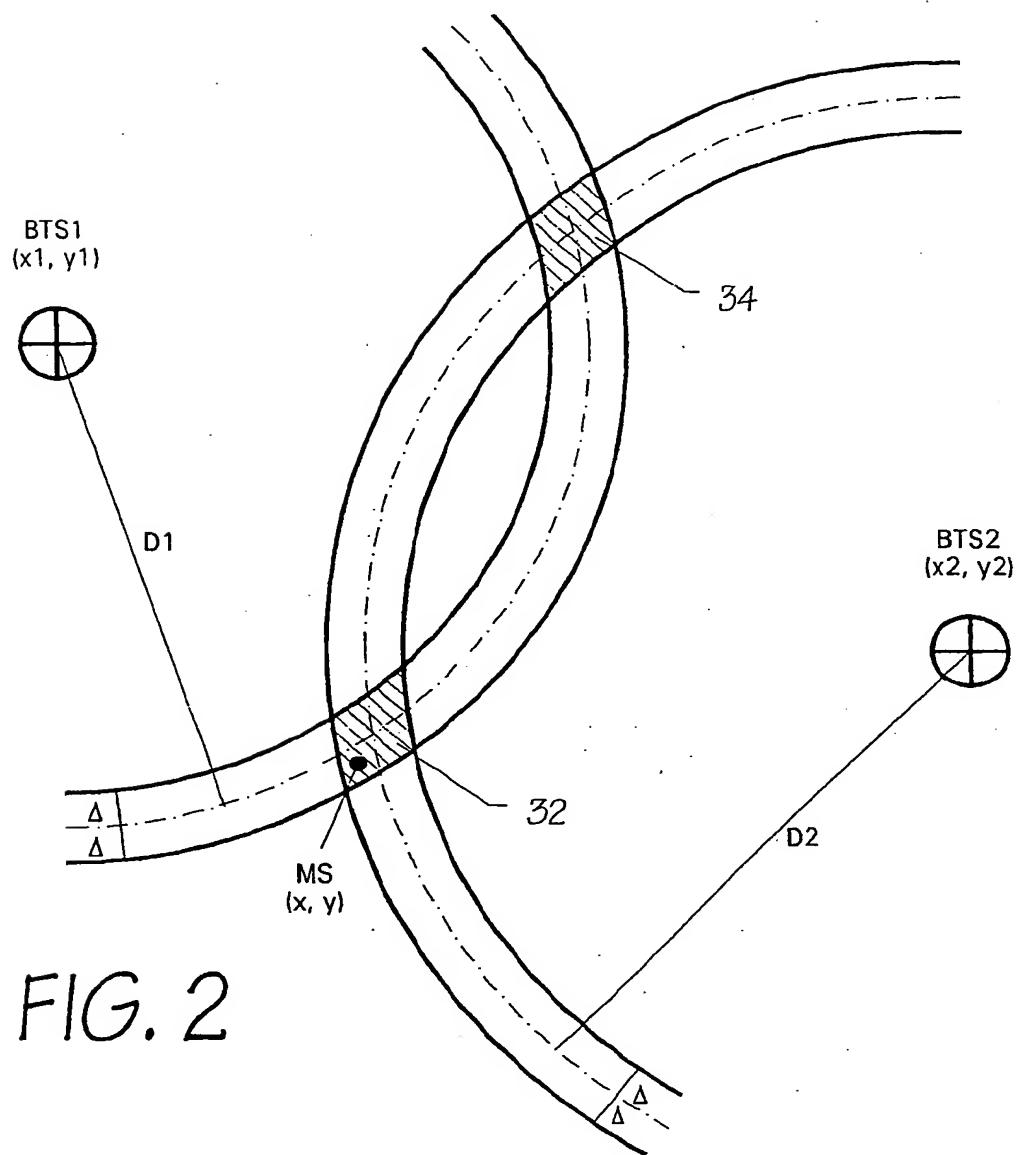


FIG. 2

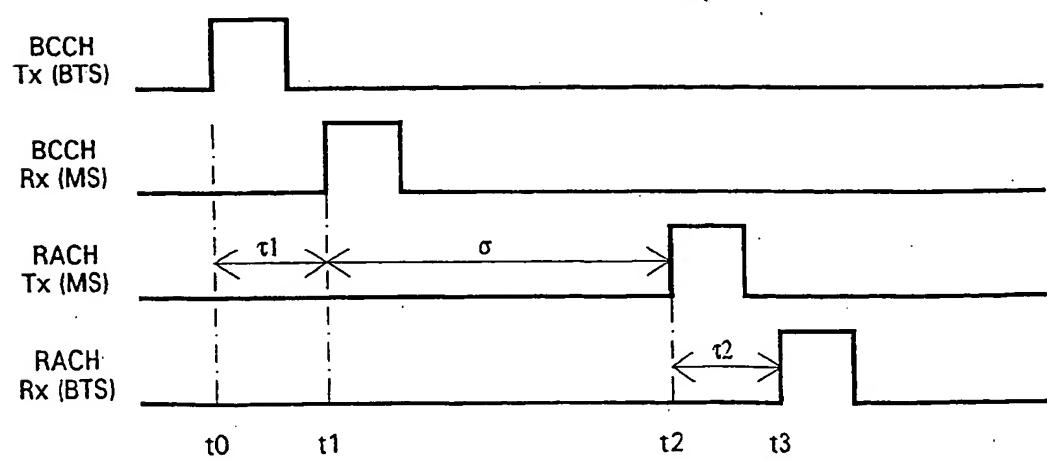


FIG. 3

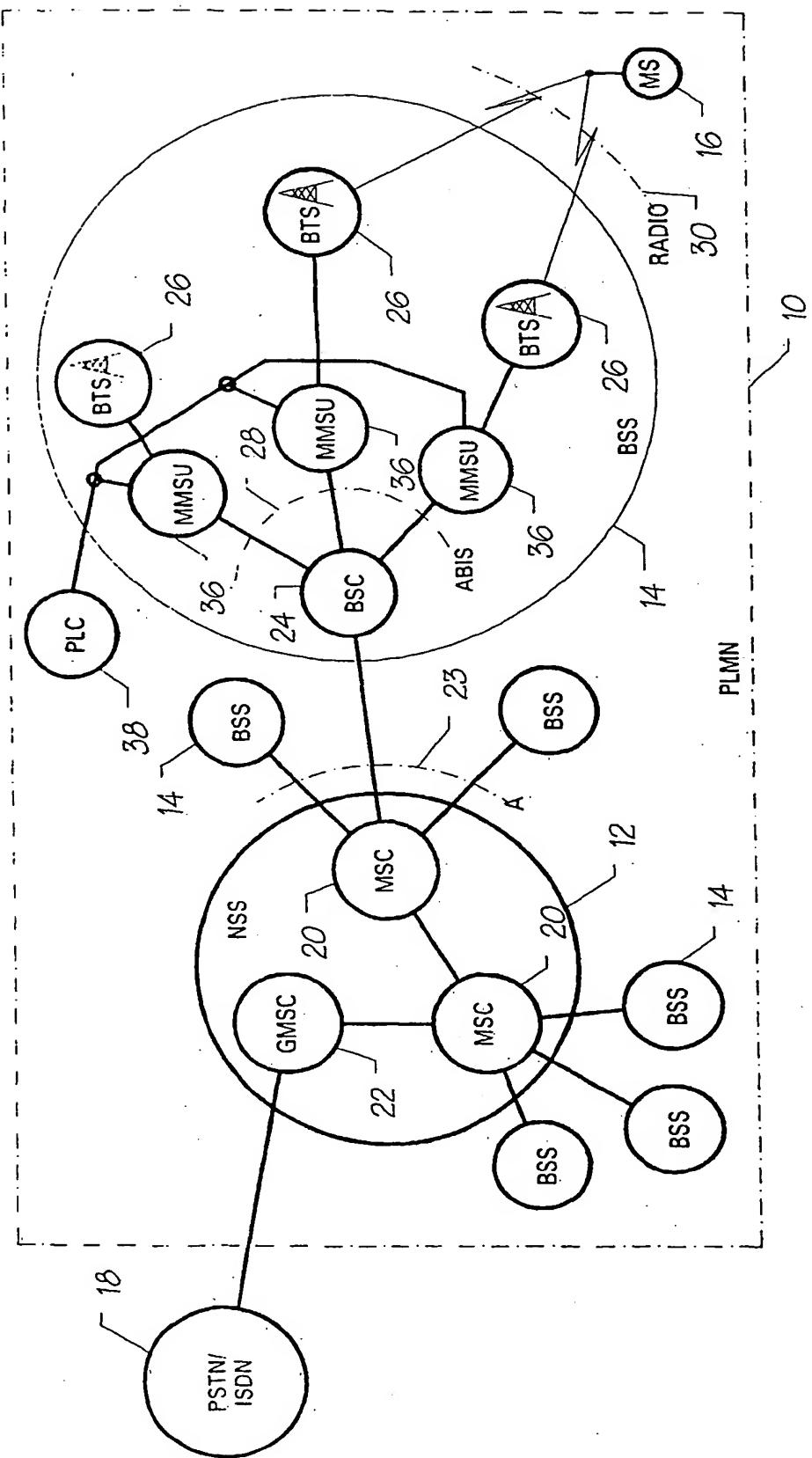


FIG. 4

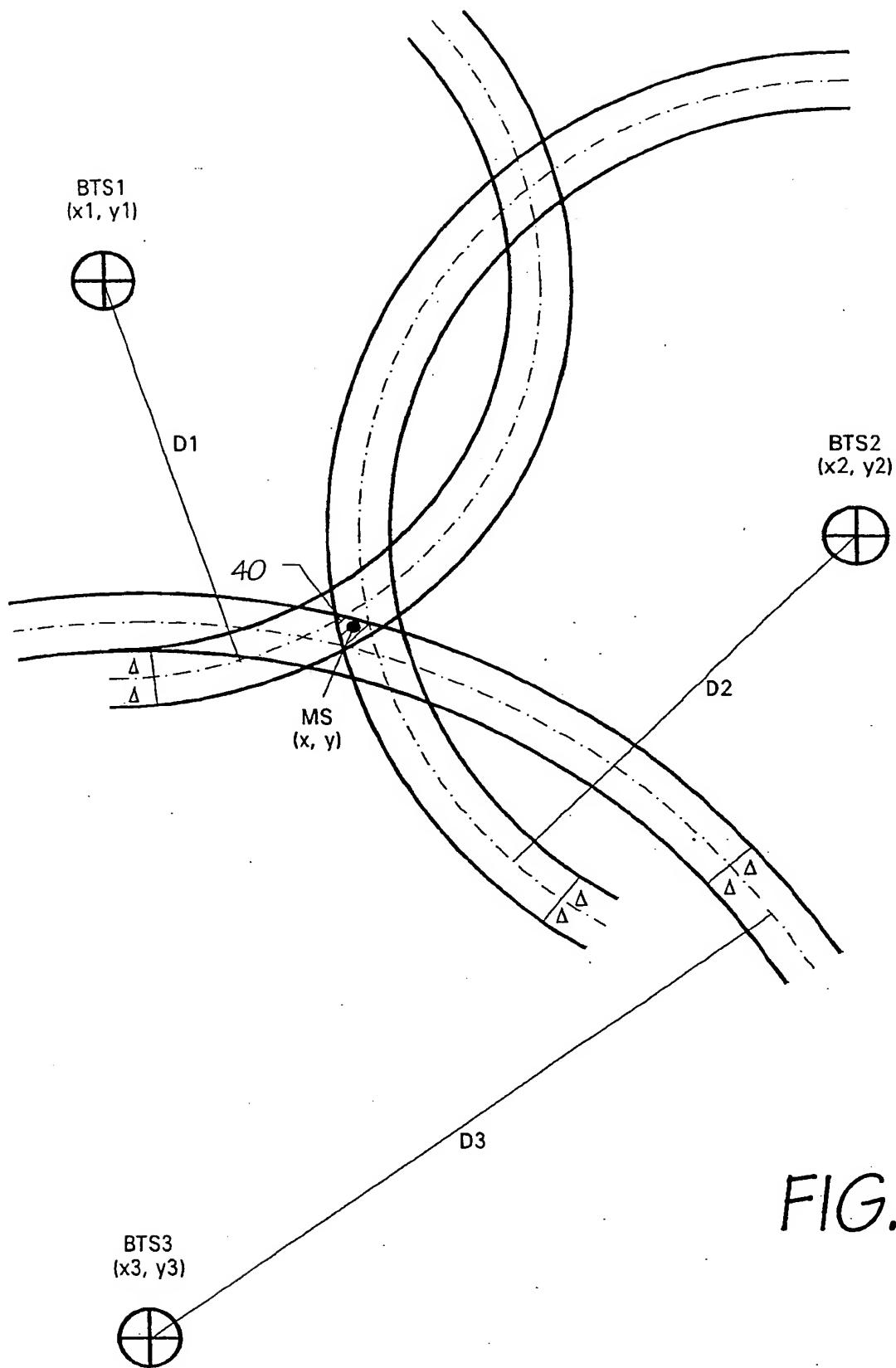
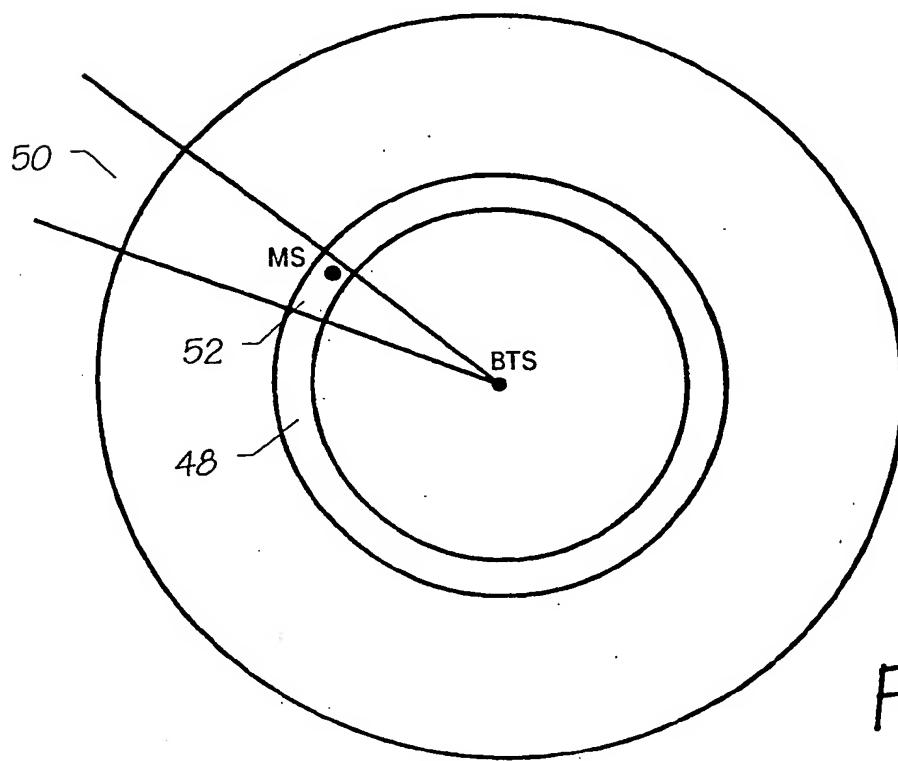
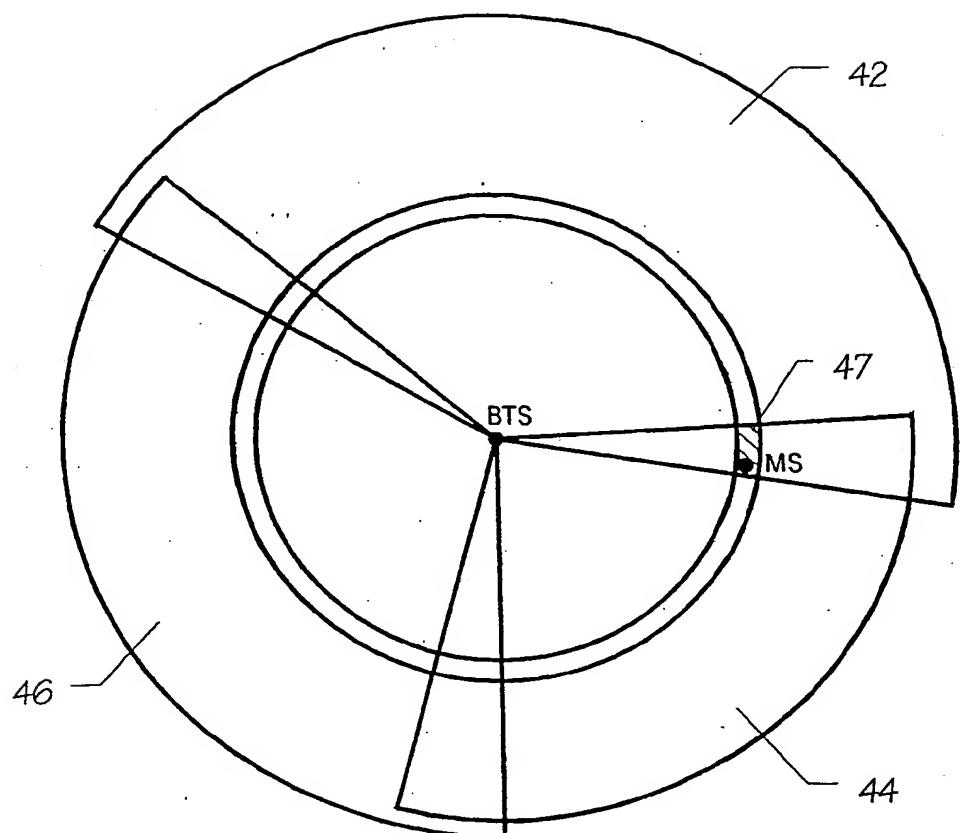


FIG. 5





## EUROPEAN SEARCH REPORT

Application Number  
EP 96 30 2345

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
X	EP 0 398 773 A (MATRA COMMUNICATION) 22 November 1990	1-3,18	H04Q7/22
Y	* column 3, line 4 - line 35 * * column 5, line 11 - column 6, line 22 * * column 6, line 30 - column 7, line 10 * ---	5,11	
Y	WO 96 04155 A (TRACKMOBILE INC) 15 February 1996	5	
A	* page 4, line 23 - page 5, line 14 *  * page 13, line 1 - line 20 * * page 14, line 35 - page 17, line 14 * ---	8,9, 13-15	
Y	EP 0 241 565 A (ANT NACHRICHTENTECH) 21 October 1987	11	
	* column 3, line 14 - line 37 * * column 3, line 53 - column 5, line 16 * * column 5, line 31 - column 6, line 34 * ---		
A	WO 93 19560 A (MOTOROLA INC) 30 September 1993	1,11	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
	* page 7, line 19 - line 37 * * page 9, line 10 - line 15 * * page 9, line 30 - page 10, line 2 * ---		H04Q
A	GB 2 260 050 A (NIPPON ELECTRIC CO) 31 March 1993	1-3,13, 17,18	
	* page 2, line 7 - line 18 * * page 3, line 10 - page 5, line 5 * * page 11, line 26 - page 12, line 22 * * page 13, line 11 - line 16 * * page 14, line 9 - line 24 * * page 15, line 6 - line 18 * ---		
		-/-	
The present search report has been drawn up for all claims.			
Place of search	Date of completion of the search	Examiner	
THE HAGUE	19 September 1996	GERLING J.C.J.	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			



## EUROPEAN SEARCH REPORT

Application Number  
EP 96 30 2345

DOCUMENTS CONSIDERED TO BE RELEVANT															
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)												
A	WO 92 05672 A (TELEVERKET) 2 April 1992 * page 3, line 7 - line 21 * * page 4, line 24 - page 5, line 30 * * page 5, line 39 - page 6, line 5 * * page 6, line 9 - line 15 * * page 6, line 30 - line 33 * --- A WO 94 27161 A (ASSOCIATED RT INC) 24 November 1994 * page 5, line 6 - page 6, line 8 * * page 9, line 20 - line 30 * * page 10, line 13 - line 24 * * page 11, line 14 - line 21 * * page 13, line 12 - line 24 * * page 39, line 16 - page 40, line 29 * -----	1-3, 12-15,18 1,12-16													
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)												
<p>The present search report has been drawn up for all claims.</p> <table border="1"> <tr> <td>Place of search THE HAGUE</td> <td>Date of completion of the search 19 September 1996</td> <td>Examiner GERLING J.C.J.</td> </tr> <tr> <td colspan="3">CATEGORY OF CITED DOCUMENTS</td> </tr> <tr> <td colspan="3">           X : particularly relevant if taken alone            Y : particularly relevant if combined with another document of the same category            A : technological background            O : non-written disclosure            P : intermediate document         </td> </tr> <tr> <td colspan="3">           T : theory or principle underlying the invention            E : earlier patent document, but published on, or after the filing date            D : document cited in the application            L : document cited for other reasons            &amp; : member of the same patent family, corresponding document         </td> </tr> </table>				Place of search THE HAGUE	Date of completion of the search 19 September 1996	Examiner GERLING J.C.J.	CATEGORY OF CITED DOCUMENTS			X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document		
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European Patent Office

### CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims

- All claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for all claims.
- Only part of the claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and those claims for which fees have been namely claims:
- No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

### LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of the unity of the invention and relates to several inventions or groups of inventions, namely:

- All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims
- Only part of the further claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respects of which search fees have been paid, namely claims:
- None of the further claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:



**LACK OF UNITY OF INVENTION**

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions, namely:

- 1- Claims 1-3,5,7,8-18 : Position locating method using handover process.
2. Claim 4 : Distance measuring method using transmission delay.
3. Claim 6 : Position location method using transmission delay and mobile bearing.
4. Claim 19 : Monitoring and message modification device.